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F I N A L   P R O G R E S S   R E P O R T

CONTRACT N7onr-35805

DIVISION OF ENGINEERING

BROWN UNIVERSITY

PROVIDENCE, RHODE ISLAND

June 1953

Sponsored by:

Office of Naval Research

Contract N7onr-35805

Project NR-061-078

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## FINAL PROGRESS REPORT

CONTRACT N7onr-35805

### I. INTRODUCTION

Early in 1942 it was decided that the Division of Engineering, Brown University would construct a transonic-supersonic wind tunnel. Funds were appropriated by the University to carry the project to completion and to provide a suitable building.

A survey of available land was made and the site chosen was a location adjacent to Merino Pond in the Olneyville section of Providence. Although this site is approximately four miles from the University, and on the opposite side of the city, it has the advantage of an adequate cooling water supply and is remote from any residential section of the city.

The design work on the wind tunnel was completed in the spring of 1948. Construction was started in the summer of 1948 at the Mechanical Engineering Laboratory. All major components of the wind tunnel were completed by March 1949. At this same time the building, which had been started in the fall of 1948, was completed and the wind tunnel was moved to the new building and set up. By May 1949 the installation was complete and ready for initial operation test runs. The relatively short time from conception to completion was evidence of the enthusiasm of the personnel associated with the project.

June 15, 1949, fundamental research was started at the installation, now known as the Engineering Research Laboratory of Brown University, under the sponsorship of the Office of Naval Research, Contract N7onr-35805.

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At this time the proposed projects to be studied were the blocking effects in the transonic range and the low pressure ratio starting of supersonic test sections.

II. PROGRESS OF THE ENGINEERING RESEARCH LABORATORY DURING THE PERIOD OF OFFICE OF NAVAL RESEARCH SPONSORSHIP

A. Development and Improvement of the Wind Tunnel Facility

The theoretical work on the blocking effects in the transonic range was not completed at this time and therefore the first project attempted concerned the development of a flexible nozzle and a variable supersonic diffuser that would permit low pressure ratio starting of supersonic test sections. The result of this investigation provided the wind tunnel with a flexible nozzle fabricated from laminations of plywood. With this arrangement it was possible to vary the Mach number during a test without the usual delay associated with fixed nozzle operation. A variable diffuser was also installed, but exhaustive tests were not made because the theoretical work on transonic model sections was then completed and the importance of this latter project was already apparent.

The first slotted wall model section was installed in December 1949. Successive modifications were indicated by the experimental results obtained. A test series was run employing three geometrically similar two dimensional wings of relatively high blocking area. The results were compared with the data obtained with the same models in a solid wall test section, (Ref. D). The conclusions of the test series established the importance and practicability of the slotted wall model section for the subsonic portion of the transonic regime.

The elimination of wall interference in the supersonic portion of the transonic range appeared to show more promise when perforated rather than slotted walls were used. The theory available at this time did not seem to explain adequately the flow mechanism for perforated walls, and therefore a test program was executed at subsonic speeds to investigate the mixing process between the main stream and the flow through the perforations. The results of these experiments checked surprisingly well with the proposed theory, (Ref. H & Ref. G). Further experimental work at higher speeds will be conducted when time permits.

It was realized at the beginning of the wind tunnel project that an air drying system should be employed if supersonic testing was to be accomplished. Time and lack of funds prevented the inclusion of an air drying unit in the project until sponsorship by the Office of Naval Research was obtained. Design of this unit was started in the fall of 1949 and installation was completed in the spring of 1951, (Ref. E). The seemingly long period required to complete this project was due to the fact that the toolmakers were used on this project only when pressing work was not available.

For more routine testing it was necessary to install a three component balance. This project was initiated as early as 1949 and complete installation was accomplished in 1953. Again the apparent delay was only because this project was used as a fill-in between the machine work necessary on the current project. By operating these projects concurrently the time of two toolmakers has been fully utilized.

B. Training of Personnel

Since the beginning of this overall project generous use of graduate assistants has been the policy. By this, it was possible to give graduate students ample practical experience and thereby enhance their usefulness when they received their degrees.

Personnel formerly associated with this project now hold many responsible positions.

2 Aerodynamicists	Cooperative Wind Tunnel, Pasadena, Cal.
1 Fluid Dynamicist	John Hopkins University, Baltimore, Md.
1 Fluid Dynamicist	Builders Iron Foundry, Providence, R. I.
2 Designers	G. E. Gas Turbine Laboratory, Lockland, O.
1 Aerodynamicist	A.P.L., Silver Spring, Md.

In addition to the above, the staff now employed at the Engineering Research Laboratory is highly trained in the operation and utilization of transonic wind tunnels, and naturally, the staff has had considerable experience in dealing with the particular problems associated with the transonic wind tunnel.

III. FUTURE AIMS

At present the Engineering Research Laboratory of Brown University has equipment and personnel capable of undertaking aerodynamic projects, fundamental research or routine testing in any Mach number range below a Mach number of 2 and are especially capable of handling projects related to the difficult transonic range.

A project now in progress deals with the investigation of the aerodynamics of a scale model of a production fighter plane in the transonic range (Mach 0.9 to Mach 1.1). In 1948, when this facility was being constructed, there was not a wind tunnel facility in operation that was capable of performing this work.

It is expected that test programs will be made on the following projects.

1. Strength of shock reflections from slotted walls.
2. Nature of shock reflections from perforated walls.
3. Testing of various wing profiles in the transonic range (0.8→1.2).
4. Supersonic cascade testing.

#### IV. REPORTS ISSUED BY ENGINEERING RESEARCH LABORATORY UNDER ONR SPONSORSHIP

- A. WT-2 Technical Report, Division of Engineering, Brown University, January 1950, The 9 inch by 9 inch Transonic-Supersonic Wind Tunnel, by G. F. Anderson and P. F. Maeder.

In the report a general description of the wind tunnel facility is given.

- B. WT-4 Technical Memorandum, Division of Engineering, Brown University May 1950, Note on Deblocked Transonic Test Sections by P. F. Maeder

Confidential A theoretical derivation of the blocking effect is made and conclusions are found for the slot configuration that should produce a deblocked test section.

- C. WT-5 Internal Report, Division of Engineering, Brown University January 1951, Investigation of Turbulence in the Brown University 9 inch by 9 inch Transonic-Supersonic Wind Tunnel by W. G. Reynolds.

Description and results of turbulence tests.



- D. WT-6 Technical Report, Division of Engineering, Brown University  
April 1951, Investigation of Tunnel Boundary Interference on Two  
Dimensional Airfoils Near the Speed of Sound by P. F. Maeder

Confidential The theory of wall interference is extended and  
compared to experimental results.

- E. WT-7 Technical Report, Division of Engineering, Brown University  
May 1951, Design of the Air-Drying Unit for the Brown University  
9 inch by 9 inch Transonic-Supersonic Wind Tunnel by Gordon F.  
Anderson

A description and the theory of design of the air drying unit  
employed in the wind tunnel facility is given.

- F. WT-8 Technical Report, Division of Engineering, Brown University  
September 1952, Investigation of Losses in Wind Tunnel Test  
Sections Fitted With Slotted Walls by David Adamson and James B.  
Carroll

Confidential Experimental results are given for the momentum loss  
found downstream of slotted wall test sections.

- G. WT-9 Technical Report, Division of Engineering, Brown University  
(To be distributed soon) Boundary Condition at a Perforated Wall  
by P. F. Maeder

Confidential A new theory of the boundary condition at perforated  
walls is presented and compared with experimental results.

- H. WT-10 Technical Report, Division of Engineering, Brown University  
(To be distributed soon) Investigation of the Flow with a Perforated  
Wall Boundary by P. F. Maeder and J. F. Stapelton

Confidential The mixing process associated with a perforated wall  
boundary was investigated. Theoretical and experimental results are  
compared.

Prepared by: *Gordon F. Anderson*